

NON INTRUSIVE CHECK VALVE DIAGNOSTICS AT BRUCE A

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Abstract

Bruce A purchased non intrusive check valve diagnostic equipment in 1995 to ensure operability and availability of critical check valves in the Station. Diagnostics can be used to locate and monitor check valve degradation modes. Bruce A initiated a pilot program targeting check valves with flow through them and ones that completed open or close cycles. Approaches to determine how to confirm operability of passive check valves using non intrusive techniques were explored. A sample population of seventy-three check valves was selected to run the pilot program on prior to complete implementation. The pilot program produced some significant results and some inconclusive results. The program revealed a major finding that check valve performance modeling is required to ensure continuous operability of check valves.

Introduction

Non intrusive check valve diagnostic equipment has evolved over the past few years to become a viable maintenance tool. Increased computing speeds and storage space has made complex data collection much easier and cheaper to do. Non intrusive diagnostics for check valves can utilize two or more acoustic channels and also include AC magnetic excitation and sensor coils to collect magnetic flux change data. Other types of diagnostic data can be collected too -- such as pulse echo ultrasonics and DC magnetics. Acoustic data collected from temporarily installed accelerometers is used to identify internal impacts, rubbing, rattling, or chatter. AC magnetics is used to track the disc as the check valve opens, closes or is moving in midstream. Combining these techniques allows us to detect check valve degradation modes and

determine their severity. Comparison to similar valves helps to determine which of the valves requires maintenance.

A sample population of seventy-three check valves was selected to run a non intrusive check valve pilot program in the Station. The focus of the pilot program was to use diagnostics on a variety of check valve applications to confirm the existence and severity of degradation modes. The program would determine if it is possible to locate faults in check valves that see steady state flow conditions as well as those that are exercised during pump duty change over or when safety system tests are performed. Approaches to handle passive check valves that cannot be exercised also need to be addressed. This pilot program would identify difficulties encountered in collecting the data needed to run an effective program in a Candu Station. Any weaknesses will be located in the pilot program enabling us to make enhancements prior to full scale implementation of the check valve program.

Background

The majority of check valves at Bruce A are categorized as swing check valves. Typically, a disc is hung on a hinge arm and the arm is pinned to the valve body to allow the disc to open and close in the fluid flow path. As flow stops, the disc falls into the flow path and seals against the seat to prevent reverse flow. If the disc fails to close, severe transients can be experienced such as a feedwater piping system water hammer that caused several million dollars in damage and lost production at San Onofre Nuclear Station in the US.

Advantages of swing check valves includes: simplicity and low cost, low flow resistance, a low pressure drop across the valve, it achieves seating easily, it is tolerant to contaminants (mud, solid particles) and its ease to maintain and repair due to its relatively low accuracy requirements in seat plane orientation. Disadvantages are: a slow dynamic response leading to higher pressure surges due to reverse flow, a high wear rate and more frequent

maintenance if used in continuous operation at a flow velocity below that required for full open.¹

The swing check valve's potential high wear rate makes it a good candidate for performing non-intrusive diagnostics to screen out good and bad actors in order to prioritize maintenance activities.

Pilot Program Test Sample

The following check valve groups and operating conditions were selected:

- a) HPECI 1/3/4-34330-NV115, 116, 117, 118 (12 valves , passive)
- b) Liquid zone control 1/3/4- 34810-NV35, 38, 45, 48, 51 (15 valves, active)
- c) Boiler feedwater 1/3/4-43230-NV5, 6, 7, 8, 17, 18, 116, 117, 118, 119. (30 valves, active)
- d)Low pressure service Water 1/3/4- 71310-NV 6, 16, 26, 36. (12 valves, active)

These additional valves were tested as requested by Operations.

- a)Fueling Machine Auxiliaries North East and North West were analyzed for leakage problems. (8 valves, active)
0-35230-HP-NV1
0-35230-HF-NV1
0-35230-HLL-MV1
0-35230-HDP-MV1

- b)Moderator 32110-NV3, 4 were looked at as part of post maintenance testing. (2 valves, active)

Resources Required

Equipment:

Liberty Technologies' Quickcheck II data acquisition system with acoustics and AC magnetics was purchased in 1995. The equipment was capable of collecting data on carbon steel and stainless steel valves up to thirty inch NPS. This would be validated during the pilot program. The equipment was selected because it appeared to be the easiest to use to collect and interpret the data.

¹ NMAC Application Guide for Check Valves in Nuclear Power Plants ,Rev 1.

Two 166 MHz analysis computers were purchased to speed up analysis time, playback acoustic data and data storage. The data could be analyzed in a quieter environment. One computer was to be used by the Mechanical Maintenance Crew and the second one was to be used by the Maintenance Support Engineer for analyzing data.

People:

The pilot required 718 hours of Mechanical maintenance time to collect data and 596.5 hours of service maintenance time for scaffold and insulation requests. As the mechanics gained experience, data collection time lowered. Approximately 280 hours of engineering time was spent. In comparison, if valves are inspected internally, scaffold and insulation removal would still be required. Thus, if the pilot study showed that disassembly could be avoided, the cost of replacing parts, preparing permitry to isolate the check valve and labour to inspect the valve could be saved. Valuable maintenance resources could be allocated elsewhere during outages.

Training:

The vendor's basic introductory course was attended on site by four mechanical maintenance personnel and two maintenance support engineers. The training familiarized us with the equipment operation and data collection. Later on, two mechanical maintenance personnel attended a week long course sponsored by EPRI at Utah State University. The indoor flow loop in Utah allowed data collection on a variety of valves under various flow conditions.

Field Conditions

Testing was done under a variety of flow conditions as system availability parameters dictated. Some valves were analyzed under steady state condition. Others were looked at when valves were exercised from closed to opened or visa versa as pumps were stopped or started.

The ideal test conditions would include the check valve being closed, introducing full flow to it, monitor it as it opened, monitor it in its

steady state, stop the flow and monitor the closing stroke, monitor its closed position and look for backflow leakage. Realistically, boiler feedwater pump discharge check valves could only be exercised against system pressure by stopping or starting a pump. Opening, closing and steady state conditions were monitored for liquid zone check valves, low pressure service water check valves, HPECI check valves and moderator check valves. Steady state data was collected on other boiler feedwater system check valves.

It was recognized that performing the optimum test would be difficult to do. Creating the field conditions to test the valves was a new approach. Systems may require modifications just to test the check valve. To remedy this situation, a COG proposal was initiated to study the requirements of doing a better test (stroke open-full flow test-close-back leak check) similar to Condition Monitoring and Exercising proposals being studied for light water reactors by ASME OM-22. Unfortunately, the COG research was initiated but not completed.

Non Intrusive Test Results

FEEDWATER (steady state data)

Steam Generator inlet check valves -- Field conditions only allowed steady state data to be collected on steam generator inlet check valves as feedwater flow could not be interrupted on running Units. Magnetic and acoustic data showed the discs to be fluttering on some of the check valves. The acoustic data indicated that some impacting was occurring between the disc or hinge and valve body. Comparisons of data indicated some check valves were being exposed to wear conditions that differed from others in similar service. The data identified the presence of wear mechanisms that can lead to future inoperability if not corrected. A separate analysis of wear rates of the internal components is required to establish an appropriate disassembly frequency.

Internal inspections of the tested check valves located worn internals. The check valve with the highest impact energy and magnetic oscillations had the most worn internal parts.

The inspection supported the findings of the non intrusive data.

A side result of our non intrusive testing pilot was determining that Unit 3 check valves were listed as being manufactured by Hopkinson but were actually ACME Kerotest/Guelph Engineering swing check valves. The responsible system supervisor was advised that intended spare parts were incorrect prior to the mechanics working on the job.

FEEDWATER(exercising)

Pump discharge check valves -- Valves on Unit 3 were monitored when the pump was shut down. Acoustic data showed the flow noise to decrease as the pump coasted to a stop and then increase a short time later. The data appeared to show the valves were passing and feedwater flow was reversing through the check valve. A review of the flowsheet revealed an alternate flow path existed through a return orifice used to keep the standby pump ready. A manual valve would have to be closed prior to doing the test to check for leakage. The magnetic trace shows a change in the magnetic flux when the valve is closed and when flow is passing through the check valve. This indicates the valve internals are moving and as a result of the movement, internal parts are wearing.

The non intrusive test analysis is consistent with the maintenance history on these feedwater check valves. Hinge pins and bushings have been replaced periodically due to wear. All Units have been inspected and repaired. Improved service life can be achieved if wear analysis is used to optimize internal geometry or determine a more favourable material combination. Periodic parts replacement may be extended.

LIQUID ZONE

Compressors -- Data was collected for liquid zone compressor discharge check valves during the running cycle. Start up, valve opening, steady state, shutdown and valve closure data was collected while it compressed a mixture of helium and light water. Acoustic data showed severe and frequent impacting of the disc and backstop. Magnetic data also revealed large

oscillations of the disc. This would be considered a severe service application for a swing check valve. Wear is expected to be present on the hinge pin or hinge arm. The magnetic traces show the disc motion as well as some signal drift. The vendor attributes this to thermal changes in the valve affecting its magnetic characteristics as it warms up.

Internal inspection revealed wear on the sides of the hinge arm that contacts the side of the valve body and wear on the hinge pin locating pin holes worn locating pin holes in the hinge pin. An application review was recommended to the Responsible System Engineer -- the swing check valve is not the best suited valve for the application it is in. This application has had an ANSI 150 class swing check, ANSI 600 class swing check and now an ANSI 1878 class soft seated swing check valve. The latest swing check valve has resulted in two reactor power set backs on our Reactor Regulating System. One was due to the loss of the soft seat and wear, the second was a result of the maintenance done to replace the soft seat.

Pumps -- Data was collected on the liquid zone pump discharge check valves when pump duty changeovers were done. An acoustic beat frequency shows up when the two pumps run. One check valve has very little movement of the disc while the second check valve has more noticeable oscillations present.

Maintenance history reveals a pattern of repairs being made to these valves due wear, passing, damaged seats and also valve replacement. The maintenance history is less for the pump check valves than for the compressor check valves. However, wear modeling could help determine the appropriate maintenance interval or extend it through geometry changes or improved wear material combinations.

HPECI

Data was collected on high pressure emergency coolant injection check valves in conjunction with safety system testing being performed. Several new problems were encountered when trying to collect data.

1) High radiation fields required the acquisition equipment to be located as far away from the valve as possible -- the valve could not be heard or seen while being exercised. Long data acquisition times were needed and events could not be aligned to accurately correspond with the data.

2) Cables were hung in the air in order to reach the valves and were swinging. The movement distorted the magnetic traces. Cables would have to be secured from moving with tape.

3) These check valves have a pneumatic actuator on them for testing purposes. The mechanics had to use a phone to contact the first operator to coordinate stroking and data collection. Portable communication devices were discovered to severly disrupt the magnetic signal data.

4) Only one stroke per valve was allowed so setup could not be optimized. More testing will be needed to locate the correct sensor positions, gains and magnetic field strength. The vendor is testing equipment to see if higher fields can be generated without destroying the magnetic coils.

Acoustic and magnetic signals were inconclusive due to the difficulties we encountered. We only picked up the drone of the heat transport motors in the background acoustically and the magnetic trace did not reveal a crisp, clean open stroke on any ECI valve tested. The reliability of the magnetic trace is suspect due to the unsecured cabling and interference from communication devices.

More work is required to collect data on this application. It could not be distinguished if the actuator stem was rising and falling with the disc attached or if the disc was missing (unlikely). Disc seat impacts were not located on any valves. Filtering signals did not provide any further information. Relocation of acoustic and magnetic sensors may help to obtain better data.

LOW PRESSURE SERVICE WATER

Thirty inch ANSI class 150 swing check valves are in service in the low pressure service water system. Four similar valves were monitored. Pump starts and stops were monitored to catch the open and close stroke of the valve. Two of

the four check valves had crisp magnetic traces that looked as if they were done under laboratory conditions. The magnetic trace was flat, until a step change occurred due to the pump start, followed by mild oscillations and a second step change as the check valve opened once differential pressure was overcome. The acoustic trace showed an increase in sound energy as the pump started followed by a large impact as the hinge hit the back stop and finally some minor impacts as the disk rattled in the flow.

One check valve showed much larger oscillations in its magnetic trace. The trace showed the valve disc or hinge arm to be moving while the acoustics showed little change in acoustic energy or increased impacting. A pump stop was monitored to collect data as the valve closed. The acoustic trace showed the pump noise stop, the check valve slam closed, a short duration quiet period and a slight rise in the flow noise. The check valve was suspected of passing flow in the reverse direction.

Internal inspection revealed the following: its soft seat o-ring was missing and probably had been for several years, one of two hinge pin bushings was missing causing misalignment between the disc and seat, the seat was wire drawn due to cavitation which confirmed the reverse flow leak path. Visual observation of the pump shaft did not reveal any sign of the reverse flow (backwards rotation). If the pump had been started up while rotating backwards, it could have been severely damaged or the start up motor current could have overloaded a power bus.

FUELING MACHINE AUXILIARIES -- NORTH EAST AND WEST

Maintenance personnel responsible for the fueling machine auxiliaries' systems knew they had one or more check valves passing out of four possible check valves resulting in a loss of pressure. Normally, they would have to remove each check valve until they found the one that was passing. The approach is high hazard work from a radiation dose point of view. Field conditions were set up and an accelerometer was mounted to each check valve. One check valve out of the four showed an increase in flow noise

as a motorized globe valve was closed. The incompressible fluid was being squeezed out past the check valve. Since the other three check valves did not exhibit the same characteristic, it was declared as the passing valve.

Internal inspection revealed a partial o-ring to be stuck between the disc and seat preventing tight closure resulting in a passing valve. No other valves required maintenance. ALARA principles were followed and time savings resulted from using the diagnostic equipment approach to find the passing valve.

MODERATOR

Two moderator pump discharge check valves were monitored during pump start, running and shut down after maintenance was performed. The magnetic trace revealed oscillations while running indicating the valves are susceptible to wear degradation.

Periodic maintenance is performed to replace worn internal parts to prevent leakage. Wear analysis modeling could improve internal geometry or material combinations to extend parts replacement intervals.

Problems/Improvements

The pilot program revealed several areas where improvements could be made to overcome problems encountered in the field.

One area to improve on is how the equipment is set up. Sensor locations were selected based on vendor training input. Often the locations could be optimized to improve data collection. Selecting gains and current settings for magnetic field strength was all done by estimates. This would all improve as the maintenance personnel learned more about the equipment and the valves being tested. The program would have to be run at the Station level to take advantage of the experience and knowledge being gained. Otherwise, details will be missed and follow up inspection activities may not be documented correctly.

Another area for improvement is creating the field conditions to ensure the best data can be collected. An application review is necessary to determine if the valve can be tested during an outage or while the Unit is operating. The data collection would have to be coordinated to align with pump duty changeovers or other activities being performed. All the Station staff tried very hard to ensure the check valve data was collected during the pilot program.

Ideally, flow, pressure and temperature data should also be collected. Caution is also necessary -- some flows cannot be varied or valves exercised to design basis conditions. Injecting light water into an operating reactor to collect data is out of the question but simulations to do the same during an outage may be feasible provided a proper risk assessment is done. The additional data can be used to model the application to improve its performance.

Program Recommendations

1) An application review is a necessity to start a check valve program. Based on the results of the non intrusive diagnostic pilot program, problems are going to be found. Solutions will be more difficult to obtain. Modeling and analysis is essential to create a technical basis for determining periodic inspection requirements, material properties and valve geometry. The answers to the following questions are required. Is the right type of NV in the system? Is the valve being tested to ensure it meets its safety requirements?

2) An operating systems review is required to determine values of V_{min} and V_{open} to screen check valves to determine if they are stable or unstable. Non intrusives can be used to verify the results.

3) Perform wear analysis to determine if internal geometry can be changed to improve performance. Actual internal dimensions and material properties will have to be determined to calculate parameters such as disc or hinge oscillation frequency. Only wear rates analysis can be used to predict periodic inspection frequency. The model can be updated and validated with actual valve wear data and material properties.

4) Ensure disc stud fatigue analysis is performed to avoid the loss of the check valve function due to a missing disc. The fatigue failure can invalidate the wear model if it is not checked. Constant back seat tapping can lead to stud fatigue if the impacts are large enough or frequent enough. Some swing check valve designs eliminate this problem.

5) Set up field conditions to test poised systems in order to perform condition-based monitoring and exercising tests on valves that are passive. Full flow test to ensure it opens. Reverse the flow and check for leakage to ensure tight closure and verify the disc is not missing. System modifications may be impractical to accommodate this type of testing.

6) Build valve operability information from SST information, leakage surveys, surveillance, maintenance inspections, and industry experience. Increased knowledge has been used to extend inspection intervals.

Conclusions

1) Non intrusive check valve diagnostics is a useful tool that locates check valve degradation modes. It can be used to prioritize work on similar valves, complete post maintenance testing and it can provide data to assist in making improved operability decisions.

2) Additional modeling is necessary to reduce or resolve the degradation modes found due to non intrusive diagnostics testing. Non-intrusive diagnostics is only a part of a good check valve program. All operability aspects must be considered.

3) The Candu Station design must be evaluated to determine if safety related check valves can utilize a better test and perform it less frequently. (full flow test and backflow leakage test)